chemical and physical hazards so as to provide wholesome, attractive and safe meat to consumers (3,8,9,10). The process also captures valuable animal health related data that can be used as an epidemiological tool for the surveillance of animal diseases (11,12,13,14). In addition, meat inspection plays a central role in the detection and prevention of transmission of zoonotic diseases into the human population (15,16).

Disease or conditions produce blemishes or lesions of a developmental, degenerative, inflammatory or neoplastic nature that make the organs or offal unacceptable for human consumption (15,16,17). Infectious (mainly parasitic, bacterial, viral) and non-infectious (traumatic, neoplasia and contamination) conditions, resulting in condemnation of offal have been extensively studied (15,18,19). Parasitic, bacterial and traumatic lesions have been reported as the major cause of lesions in offal (10,20-25). Parasitic and bacterial infections often show annual (18), seasonal (14,26,27) and even monthly patterns. Years of good rains, warmth and moisture of summer months promote intermediate host and parasite multiplication (28), while winter months promote bacterial transmission as a result of animals huddling together in order to keep warm.

Reports from previous studies indicate that livers followed by lungs, are the most commonly condemned organs/offal in cattle (17,19,25,29,30). However, other workers, have reported a higher prevalence of lung than liver condemnations (11,16,20,31). With regard to liver condemnation, *Fasciola* (18,28,32-38), followed by metacestode cysts of C*ysticercus bovis* (21) and/or *Echinoccocus granulosus* (10,16,39,40) have been reported to be the major causes of condemnation. Bacteria such as *Staphylococcus*, S*treptococcus*, *Proteus* and *Mycobacterium bovis* have also been isolated from abscesses and other lesions in condemned livers and lungs (41-43). Other causes of liver condemnation include, cirrhosis, jaundice and discolouration (10,18,44,45).

With respect to lungs, a number of authors report that pneumonia is the leading cause of condemnation (11,12,20,33,41,46). In other studies, hydatid cysts (8,10,47), *Mycobacterium bovis* (11,41) and *Mycoplasma mycoides mycoides* have been implicated (46,48). Emphysema, congestion, abscesses, atelectasis and haemorrhages are conditions that have also been identified in the lungs (11,15,25,41,47). Causes and the rate of condemnation of heart, kidney and tongue condemnations tend to vary from study to study (3,40,46).

There are a number of studies on meat condemnation from developing countries (23,49) including from West Africa (11,19,31,48,50), East Africa (20,25,33,34,44,51), particularly from Ethiopia (40,45,47,52) and Southern Africa (15,27,32,37,38,53). However, there are limited studies on meat condemnation from Namibia (3,22,54,55), although data on condemnations is available in monthly and annual reports of the Directorate of Veterinary Services in the Ministry of Agriculture Water and Forestry.

Of the studies on meat condemnation in Namibia, two focused on the condemnation of beef carcasses and organs (3,54), one determined the incidence of cysticercosis at a beef abattoir (55), while another focussed on bruising as a quality issue and a cause of condemnation in beef carcasses (22). None of the studies reported on the proportional condemnation of cattle red offal. Therefore, the objective of this study was to identify the causes and dynamics of red offal condemnations and to estimate the associated financial losses at a high throughput abattoir.

2.Materials and Methods

2.1 Study area

Namibia is located at 22°58'1.42"S and 18°29'34.80"E in the southwestern part of Africa. It is divided into 14 administrative regions. A veterinary cordon fence separates the FMD-free Southern Namibia from the FMD infected and protected regions in the north.

2.2 Study animals, slaughter and dressing procedures

Cattle destined for slaughter at the study abattoir originated from farms and a feedlot south of the Veterinary Cordon Fence of Namibia. The farms and feedlot were under continuous surveillance for animal diseases by the state veterinary service and were approved to send animals for slaughter. Slaughter animals were transported to the abattoir by road in approved transport vehicles. On the day of arrival, cattle were subjected to ante-mortem inspection in holding pens. After overnight rest, slaughter was achieved through jugular vein and carotid artery exsanguination of captive bolt stunned cattle. Thereafter, electrical stimulation and carcass dressing (head, hide and hoof removal, evisceration and splitting of carcasses) were performed as per abattoir standard operating procedures and following hygiene standards based on the Hazard Analysis and Critical Control Point (HACCP).

2.3 Study design and data collection

Daily condemnation records for cattle slaughtered at the export abattoir from 2016-2018 were retrieved and used for this study. Records included results of ante-mortem inspection, number of animals slaughtered and organs condemned at post-mortem or meat inspection. Post-mortem inspection was performed on correlated carcass halves and offal by trained meat inspectors under the supervision of a qualified state veterinarian. The meat inspection service at high throughput or export abattoirs in Namibia is administered by government officials from the Directorate of Veterinary Services (DVS) within the Ministry of Agriculture Water and Forestry (MAWF). Post-mortem inspection was performed through visual appraisal of organ colour and morphology, palpation to ascertain organ consistency and systematic incisions into the visceral organs according to the procedures prescribed by the Meat Safety Act (Act No. 40 of 2000). Suspicious samples were submitted to the Central Veterinary Laboratories (CVL) for confirmatory diagnosis.

Meat that passed inspection was washed, graded, weighed and immediately chilled. Condemned carcasses and offal were passed through a designated condemnation channel to the condemnation room for treatment at the by-products area or for direct disposal. For the purpose of this study, red offal was designated to include the skin-off head, tongue, oesophagus, heart, lung, kidney, liver and spleen. Categories designated for analysis of condemnations included contaminations (floor, milk, pus, rumen fluid and faecal), infections (echinococcosis/hydatidosis, cysticercosis, *Stilesia hepatica*, actinomycosis and actinobacillosis), inflammation (hepatitis, peritonitis, pleuritis, nephritis and oedema) and miscellaneous conditions (haematoma/blood vessel abnormalities, emphysema, melanosis and abscess). For the purpose of seasonal analysis of condemnations in this study, two seasons were designated; the wet season (November to April) and the dry season (May to October). The monetary values assigned to red offal in this study were based on gazetted red offal prices and weights at abattoir at the time of the study.

2.4 Statistical analysis

Data on condemnations were captured onto a Microsoft Excel 2013 spreadsheet. Pivot tables were subsequently used to determine the proportional distribution of animals based on year, season, month, organ type and cause of condemnation categories. The data was exported to the Statistical Package for Social Sciences (SPSS) version 25 for further analysis. The Chi square test was used to test for association of categories and the Z test was used for comparison of proportions, where $p \leq 0.05$ was considered significant.

3.Results

A total of 251697 cattle were slaughtered at the abattoir under study over a 36-month period (Table 1) giving an overall red offal condemnation rate of 15.56% (39157/251697). The proportion of condemned organs varied with the year of study [$X^2(14) = 587.13$, $p<0.001$]. The overall proportion of condemned livers and lungs were significantly greater than those of the rest of the red offal (54.32% and 29.88%, respectively; $p<0.001$). A total of N$6 422 586 (US$364 805) was lost through condemnation of red offal during the study period and the majority of this revenue loss was attributable to liver, lung and head condemnations (62.1%, 18.3% and 10.8%; respectively). Throughout the study period, the proportion of condemned organs was dependent on the month of study [$X^2(77) = 1898.72$, $p<0.001$] and the month of June had the highest number and proportion of condemned organs (13.34%, $p<0.001$).

Throughout the study, the proportional distribution of organ condemnations varied with the season of study [$X^2(7) = 111.12$, $p<0.001$], with a higher rate of organ condemnation in winter than in the summer season (60.52% and 39.48%, respectively, $p<0.001$). The proportion of condemned lungs in the summer (12.29%, $p<0.05$) and heads, kidneys, and pluck in winter (3.82%, 0.21% and 1.25%, respectively; $p<0.05$) was significantly greater than expected.

The proportion of organ condemnations according to pathological condition was dependent on the year of study [$X^2(6) = 917.14$, $p<0.001$] (Table 2). The proportion of organs condemned due to contaminations and inflammation in 2016 (7.8% and 12.3%, respectively, $p < 0.05$), miscellaneous causes in 2017 (12.29%, $p<0.05$) and inflammation and infections in 2018 (7.5% and 4.9%, respectively, $p<0.05$) were greater than expected. Overall, the highest proportion of condemnations were due to miscellaneous causes followed in descending order by inflammation, infections and contaminations (38.3%, 29.4%, 16.6% and 15.8%, respectively, $p<0.05$).

Overall, the proportion of organs condemned per pathological condition varied with the month [$X^2(33) = 1461.7$, $p<0.001$] (Table 3) and season of study [$X^2(3) = 82.61$, $p<0.001$]. The proportion of organs condemned due to contaminations in March and April (1.7% and 2.0%; respectively, $p<0.05$); inflammation in March,

Table 1: Proportions and value of organs condemned at theabattoir from 2016 to 2018

	Year (n=Total slaughter)				
Organ condemned	**2016 (n=95106)**	**2017 (n=84922)**	**2018 (n=71669)**	**Overall (n=251697)**	**Revenue loss (NAD)**
Heads (%)	1048 (2.68)*	730 (1.86)	535 (1.37)	**2313 (5.91)**	**693 900 (10.8)**
Hearts (%)	148 (0.38)*	81 (0.21)	84 (0.21)	**313 (0.80)**	**43820 (0.7)**
Kidneys (%)	37 (0.09)	43 (0.11)	17 (0.04)	**97 (0.25)**	**10.541 (0.2)**
Livers (%)	7445 (19.01)	8928 (22.80)*	4898 (12.51)	**21271 (54.32)**	**3990546 (62.1)**
Tongues (%)	538 (1.37)*	344 (0.88)	224 (0.57)	**1106 (2.82)**	**203485 (3.2)**
Lungs (%)	4708 (12.02)*	4096 (10.46)	2896 (7.40)*	**11700 (29.88)**	**1177313 (18.3)**
Gullets (%)	968 (2.47)*	409 (1.04)	318 (0.81)	**1695 (4.33)**	**14018 (0.2)**
Plucks (%)	275 (0.70)	265 (0.68)	122 (0.31)	**662 (1.69)**	**288963 (4.5)**
Total (%)	**15167 (38.73)[a]**	**14896 (38.04)[a]**	**9094 (23.22)[a]**	**39157 (100.00)**	**6422586 (100.0)**

*values were greater than expected since $p \leq 0.05$; values with the same suffix[a] in the same row were significantly different since $p \leq 0.05$

Table 2: Annual distribution of organ condemnations at the abattoir per pathological condition

Year	**Contaminations** (%)	**Inflammation** (%)	**Infections** (%)	**Miscellaneous[#]** (%)	**Total** (%)
2016	3071 (7.8)*	4835 (12.3)*	2165 (5.5)	5096 (13.0)	**15167** (38.7)[a]
2017	2026 (5.2)	3761 (9.6)	2405 (6.1)	6704 (17.1)*	**14896** (38.0)[a]
2018	1077 (2.8)	2926 (7.5)*	1912 (4.9)*	3179 (8.1)	**9094** (23.2)[a]
Total	**6174** (15.8)	**11522** (29.4)	**6482** (16.6)	**14979** (38.3)	**39157** (100.0)

*values were greater than expected since $p<0.05$; [#]Abscess, angioma, melanosis and emphysema; values with the same suffix within columns were significantly different since $p \leq 0.05$

Table 3: Monthly distribution of organ condemnations according to pathological condition at the abattoir

Month	**Contaminations (%)**	**Inflammation (%)**	**Infections (%)**	**Miscellaneous[#] (%)**	**Total (%)**
January	110 (0.3)	321 (0.8)	168 (0.4)	454 (1.2)*	**1053 (2.7)**
February	341 (0.9)	554 (1.4)	335 (0.9)	989 (2.5)*	**2219 (5.7)**
March	666 (1.7)*	1188 (3.0)*	606 (1.5)	1215 (3.1)	**3675 (9.4)**
April	794 (2.0)*	788 (2.0)	961 (2.5)*	1709 (4.4)	**4252 (10.9)**
May	756 (1.9)	924 (2.4)	1206 (3.1)*	1457 (3.7)	**4343 (11.1)**
June	852 (2.2)	1679 (4.3)*	922 (2.4)	1772 (4.5)	**5225 (13.3)**
July	630 (1.6)	1234 (3.2)	407 (1.0)	1822 (4.7)*	**4093 (10.5)**
August	639 (1.6)	1322 (3.4)*	608 (1.6)	1475 (3.8)	**4044 (10.3)**
September	450 (1.1)	1076 (2.7)*	380 (1.0)	1265 (3.2)	**3171 (8.1)**
October	412 (1.1)	1105 (2.8)*	375 (1.0)	929 (2.4)	**2821 (7.2)**
November	370 (0.9)	997 (2.5)	332 (0.8)	1493 (3.8)*	**3192 (8.2)**
December	154 (0.4)	334 (0.9)	182 (0.5)	399 (1.0)	**1069 (2.7)**
Total	**6174 (15.8)**	**11522 (29.4)**	**6482 (16.6)**	**14979 (38.3)**	**39157 (100.0)**

*values were greater than expected since $p \leq 0.05$

Table 4: The seasonal distribution of organ condemnations by pathological condition

Season	Contaminations (%)	Inflammation (%)	Infections (%)	Miscellaneous (%)	Total
Summer	2435 (6.2)	4182 (10.7)	2584 (6.6)	6259 (16.0)*	**15460 (39.5)**
Winter	3739 (9.5)	7340 (18.7)*	3898 (10.0)	8720 (22.3)	**23697 (60.5)**
Total	**6174 (15.8)**	**11522 (29.4)**	**6482 (16.6)**	**14979 (38.3)**	**39157 (100.0)**

*values were greater than expected since $p \leq 0.05$

Table 5: Annual distribution of liver condemnations by pathological condition

	Year			
Reason for condemnation	**2016**	**2017**	**2018**	**Overall**
Abscess (%)	3137 (14,75)	4283 (20,14)*	2054 (9,66)	**9474 (44,54)**
Contamination (%)	287 (1,35)*	243 (1,14)	138 (0,65)	**668 (3,14)[a]**
Haematomas/blood vessel lesions (%)	627 (2,95)*	555 (2,61)	251 (1,18)	**1433 (6,74)**
Hydatidosis (%)	161 (0,76)	134 (0,63)	403 (1,89)*	**698 (3.28)[a]**
Peritonitis (%)	2924 (13,75)*	2386 (11,22)	1882 (8,85)*	**7192 (33,81)**
Stilesia hepatica (%)	255 (1,20)	856 (4,02)*	146 (0,69)	**1257 (5,91)**
Melanosis (%)	53 (0,25)	346 (1,63)*	7 (0,03)	**406 (1,91)**
Septicaemia (%)	1 (0,005)	3 (0,01)	0 (0,00)	**4 (0,02)**
Blood splash (%)	0 (0,00)	109 (0,51)*	0 (0,00)	**109 (0,51)**
Actinomycosis (%)	0 (0,00)	13 (0,06)	17 (0,08)*	**30 (0,14)**
Total (%)	**7445 (35,00)**	**8928 (41,97)**	**4898 (23,03)**	**21271 (100,00)**

*values were greater than expected since $p \leq 0.05$; values with the same suffix[a] within the same column were not significantly different since $p > 0.05$.

Table 6: Reasons for condemnation and seasonal distribution of liver condemnations

	Season		
Reason for condemnation	**Summer**	**Winter**	**Overall**
Abscess (%)	3743 (17.60)	5731 (26.94)	**9474 (44.54)**
Contamination (%)	302 (1.42)	366 (1.72)	**668 (3.14)**
Hematomas/blood vessel lesions (%)	781 (3.67)*	652 (3.07)	**1433 (6.74)**
Hydatidosis (%)	464 (2.18)*	234 (1.10)	**698 (3.28)**
Peritonitis (%)	2555 (12.01)	4637 (21.80)*	**7192 (33.81)**
S. hepatica (%)	248 (1.17)	1009 (4.74)*	**1257 (5.91)**
Melanosis (%)	339 (1.59)*	67 (0.31)	**406 (1.91)**
Septicaemia (%)	0 (0.00)	4 (0.02)	**4 (0.02)**
Blood splash (%)	0 (0.00)	109 (0.51)*	**109 (0.51)**
Actinomycosis (%)	13 (0.06)	17 (0.08)	**30 (0.14)**
Total (%)	**8445 (39.70)**	**12826 (60.30)**	**21271 (100.00)**

*values were greater than expected since $p \leq 0.05$

June, August, September and October (3.0%, 4.3%, 3.4%, 2.7% and 2.8%; respectively, $p<0.05$); infections in April and May (2.5% and 3.1%; respectively, $p<0.05$) and miscellaneous causes in January, February, July and November (1.2%, 2.5%, 4.7% and 3.8%, $p<0.05$) were greater than expected.

More organs were condemned due to inflammation in winter (18.7%, $p<0.05$) and miscellaneous causes in the summer (16.0%, $p<0.05$) (Table 4). Condemnations of livers due to contaminations, hematomas/blood vessel lesions and peritonitis in 2016 (1.35%, 2.95% and 13.75%; respectively, $p<0.05$), abscess, *S. hepatica*, melanosis and blood splash in 2017 (20.14%, 4.02%, 1.63% and 0.51%; respectively, $p<0.05$) and hydatidosis, peritonitis and actinomycosis in 2018 (1.89%, 8.85% and 0.08%; respectively, $p<0.05$) were greater than expected (Table 5). A greater proportion of livers were condemned in winter than in summer (60.3% and 39.7%; respectively, $p<0.001$). The proportion livers condemned due to hematomas/blood vessel lesions, hydatidosis and melanosis were greater in the summer (3.67%, 2.18% and 1.59%; respectively, $p<0.05$), while those due to peritonitis, *S. hepatica* and blood splash were greater in winter (21.8%, 4.74% and 0.51%; respectively, $p<0.05$) (Table 6).

A higher proportion of lungs were condemned due to contamination and emphysema in 2016 (7.74% and 10.24%; respectively, $p<0.05$); contamination, pleuritis and melanosis in 2017 (6.28%, 3.44% and 2.09%; respectively, $p<0.05$) and hydatidosis in 2018 (10.34%, $p<0.05$). The proportion of lungs condemned in winter were significantly greater than those in summer (58.9% and 41.1%; respectively, $p<0.05$) (Table 7). The proportional condemnations due to hydatidosis in summer and that of pneumonia were significantly greater than expected (15.1% and 4.3%; respectively, $p<0.05$).

Table 7: Reasons for condemnation and seasonal distribution of lung condemnations

	Season		
Reason for condemnation	**Summer**	**Winter**	**Overall**
Abscess (%)	573 (4.9)	824 (7.0)	**1397 (11.9)**
Contamination (%)	787 (6.7)	1142 (9.8)	**1929 (16.5)**
Pleuritis (%)	329 (2.8)	500 (4.3)	**829 (7.1)**
Hydatidosis (%)	1761 (15.1)*	2294 (19.6)	**4055 (34.7)**
Emphysema (%)	901 (7.7)	1372 (11.7)	**2273 (19.4)**
Pneumonia (%)	231 (2.0)	498 (4.3)*	**729 (6.2)**
Melanosis (%)	230 (2.0)	258 (2.2)	**488 (4.2)**
Total	**4812 (41.1)[a]**	**6888 (58.9)[a]**	**11700 (100.0)**

*values were greater than expected since p≤0.05; values with the same suffix[a] within the same row were significantly different since $p<0.05$.

4.Discussion

Results of this study show an overall condemnation rate of 15.65% for offal over a three-year period. Our findings are much higher than the condemnation rates of less than 10% reported by other studies (11,18,35,48), but are comparable to rates of 14-18% documented by other studies (25,31,51). Offal condemnation rates reported in literature are very variable (36,42,56). This variation may be explained by differences in the animal characteristics (ages, breeds, sex, body condition) (36,38,42,57), environment (season, year, month, low lying or highland geographical location) (17,18,26) and management factors (nutrition, production system) between studies.

The cost of the red offal condemnation in this study (US$364 805.10) represents a substantial loss of revenue in the operations of an abattoir over a relatively short period. Our findings show a higher loss of revenue than a previous study in Namibia in which both carcass and organ condemnations cost the abattoir about US$143711.00 over a four year period (3). In this study, revenue lost due to liver condemnation was estimated at US$226664.33 over the three year study period. Our finding was greater than the US$79 251.60 loss that was associated with liver condemnations in a group of abattoirs in Nigeria in a five-year study (26). However, comparisons of financial losses with previous studies are complicated by variations due to differences in climate, breed studied, types of animals slaughtered, disease situations, length of the studies, meat inspection procedures and record keeping procedures among other factors.

The highest condemnation rate of livers as compared to other organs is not surprising, given its anatomical position as well as its physiological function in the body. Being the largest and central organ with a high blood flow responsible for detoxification, the liver is the organ most frequently exposed to noxious substances and infectious material (58-61), hence the high number of livers condemned due to abscesses. According to a number of studies, the major afflictions of the liver include fasciolosis, abscessation, cirrhosis, hydatid cysts and tuberculosis (10,26,31,44,45,51). Parasite larvae that penetrate the wall of the intestines or ingested infectious agents and chemicals are first carried to the liver by the portal veins, which may explain why the liver was the most condemned organ in this study.

In this study, the high rate of liver condemnation (54.32%) was primarily due to abscesses and extension of peritonitis to the liver. This rate was higher, but comparable to a condemnation rate of 51.5% reported by a similar study in the Zambezi Region (3). This finding is rather surprising considering that study cattle originated from semi-arid to arid regions, while the Zambezi Region is the wettest part of the country, where internal parasite burden on the liver is expected to contribute to a higher condemnation rate. A number of studies have identified parasites, particularly *Fasciola* (18,35-37) and hydatid cysts (10,16,40) as the main causes of liver condemnation. It is not surprising that *Fasciola* spp. was not identified in the current study because ideal environmental conditions (swamps) for the survival, multiplication and transmission of the parasite are absent in the majority of the areas supplying slaughter cattle to the abattoir. Moreover, the mostly commercial farmers south of the VCF, follow strict internal parasite drenching protocols. Liver condemnation figures from literature vary from 0.09% (27) in arid Botswana to as high as 84% (34) in tropical Uganda. One would have expected similar condemnation figures between the current study and reports from Botswana (27) with notably similar climatic conditions to those in Namibia. Reports with figures closest to those from the current study were from Western Zambia (around the Zambezi river basin) where the parasite burden is high (38).

Abscessation was the major cause of liver condemnation, leading to significant economic losses. It has been suggested that there is a strong link between rumen acidosis and liver abscessation (62,63). According to some studies, liver abscesses develop when *Fusobacterium necrophorum* bacteria in rumen wall lesions secondary to rumen acidosis, associated with grain overload or concentrate feeding, are carried to the liver by the blood circulatory system (62-65). Abscessation is a primary lesion of the livers of feedlot cattle (66,67). The parent company that owns the study abattoir operates a feedlot from which it draws most of its cattle for slaughter including cattle from communal areas, which may explain the high number of livers and lungs condemned due to abscesses. However, the possibility that farmers fed their cattle high grain rations to hasten weight gain before sending them for direct slaughter cannot be ruled out. Prophylactic treatment of cattle on high energy diets with Tylosin and vaccination to prevent abscessation has proved futile (67). Perhaps farmer education may be the most viable solution to reduce occurrence of liver abscesses in feedlot cattle.

It is similarly, not surprising that lungs were the second most condemned organ. The lungs receive all the blood for oxygenation and are at the internal organ/air interface and are thus exposed to most airborne environmental pollutants and pathogens from the air as well as from blood (58,68-70). In fact, a number of studies have cited the lung as the most condemned organ (11,16,17,20). The current lung condemnation rate of 29.88% is much higher than the 10% reported in a number of sub Saharan studies (8,19,25,31,33,41,51). However, the rate is less than the 48.8% reported in the Zambezi Region of Namibia (3). Our findings are comparable to a condemnation rate of 33.9% (17), but lower than the rate of 45.66% (11) and 96.6% (47) reported by previous studies. In this study, the major causes of lung condemnations were hydatidosis, emphysema, contamination and abscesses in descending order. It is recommended that public awareness of the hydatidosis as a potential zoonosis be created through education campaigns and that farmers periodically deworm farm dogs, but the involvement of wild carnivores as definitive or intermediate hosts may complicate control (71). The emphysema and contamination observed in the lungs is most likely a product of slaughter techniques and poor hygiene practices respectively, which require the attention of the abattoir operator.

The lower rate of condemnation in 2018 (23.22%), when compared to 2016 and 2017 (38.7 and 38% respectively) may be attributable to the higher precipitation received in 2016 and 2017. According to an official Namibian weather site, the years 2016 and 2017 each received an average of 313 mm of rain, while 2018 received 295 mm (http://weather.namsearch.com/wdhrainsummary.php). It has been confirmed that meat condemnation may increase under wet conditions when the hide is heavily contaminated with mud and dung (72). Furthermore, increased organ condemnations in the wetter 2016 and 2017 may have been a result of accelerated parasite life cycle under the hot moist conditions (17,26).

The spike in the proportion of condemnations in the month of June (13.34%) is particularly noteworthy. In Namibia, June and July are the coldest months of the year, in which respiratory conditions such as pneumonia predominate when animals huddle together in order to conserve heat (73,74). Furthermore, the month of June is associated with peak slaughter numbers at the study abattoir. According to veterinary officials, the number of cattle slaughtered in June often lead to piling of offal, delayed cleaning, packaging or freezing, which results in condemnation.

The results of the current study show more than expected lung condemnations in summer, and more than expected condemnations of heads and kidneys in winter. The high number of condemnations of lungs were due to higher rates of hydatidosis. The high prevalence of hydatidosis in winter is in agreement with those reported in other studies (75,76). According to these studies the survival and longevity of *Echinococcus* protoscolices is higher in the cold season (thereby increasing their chances of being consumed alive by dogs) than in summer.

In summer, wet conditions contribute to higher hide contamination with dung and mud (72). However, it is not clear why inflammatory conditions would increase in winter nor is there any satisfactory explanation as to why miscellaneous conditions would be higher in 2017 than 2018 and why inflammatory and infectious conditions would show the opposite trend.

From the foregoing argument, condemnation of red offal is costing beef farmers, abattoirs and the Namibian fiscus necessitating the implementation of measures to arrest the avoidable loss of income. The following measures are recommended to reduce the rate of condemnations at abattoirs: farmer education on the major causes of condemnations and mitigation measures thereof at farm level; improved communication between abattoirs or official veterinarians and farmers, especially with respect to condemnation data and ways of reducing future condemnations; and abattoir operators should ensure that all procedures and activities carried out on their premises do not promote meat condemnations.

5.Conclusion

We determined a substantial loss of revenue to the abattoir and country due to cattle organ condemnations. Livers and lungs were found to be the organs most condemned at the abattoir, mostly due to miscellaneous conditions such as abscesses, hematomas, melanosis and emphysema. The high condemnation rates for red offal have the potential to impact the food security situation in the country. Meat inspection served to prevent the transmission of hydatidosis to humans. Red offal condemnations varied with season and year.

Conflict of interest

The authors have no conflict of interest.

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References

1. Kruger B, Lammerts-Imbuwa L. Namibia National Farmers Union (NNFU) Training Manual Livestock Marketing in Namibia. Namibia National Farmers Union, Windhoek, Namibia, 2008.
2. Togarepi C, Thomas B, Kankono M. Cattle marketing constraints and opportunities in north-central communal areas of Namibia, Ohangwena Region. Livest Res Rural 2016; 28: 7.
3. Madzingira O, Chinyoka S, Yule J, *et al.* A retrospective study of carcass and organ condemnations at a beef abattoir in Namibia. Alex J Vet Sci 2018; 59: 34-42.
4. Miescher G. 2012. Namibia's red line: the history of a veterinary and settlement border. Palgrave Macmillan, New York. p 101-135.
5. Schneider HP. The history of veterinary medicine in Namibia. J S Afr Vet Assoc 2012; 83: 1-11.
6. MeatCo. Meatco Annual Report 2018/19, Windhoek, Namibia, 2019. Available at

https://www.meatco.com.na/files/files/Meatco_AR_2018_19 (1).pdf. Cited: Apr 13, 2020.
7. Meat Safety Act. Government of the Republic of South Africa, 2000. Parliament of the Republic of South Africa, Pretoria.
8. Jaja IF, Mushonga B, Green E, *et al*. Prevalence of lung lesions in slaughtered cattle in the Eastern Cape Province, South Africa. J S Afr Vet Assoc 2016; 87: 1-9.
9. Jaja IF, Mushonga B, Green E, *et al.* Financial loss estimation of bovine fasciolosis in slaughtered cattle in South Africa. Parasite Epidemiol Control 2017a; 2: 27-34.
10. Solomon T, Alemu B. Economic loss caused by organ condemnation in cattle slaughtered at Hawassa Municipal Abattoir, Southern Ethiopia, J Global Biosci 2019; 8: 5966-5977.
11. Cadmus SIB, Adesokan HK. Causes and implications of bovine organs/offal condemnations in some abattoirs in Western Nigeria. Trop Anim Health Prod 2009; 41: 1455.
12. Alton GD, Pearl DL, Bateman KG, *et al*. Suitability of bovine portion condemnations at provincially-inspected abattoirs in Ontario Canada for food animal syndromic surveillance. BMC Vet Res 2012; 8: 88.
13. Dupuy C, Morignat E, Maugey X, *et al*. Defining syndromes using cattle meat inspection data for syndromic surveillance purposes: a statistical approach with the 2005–2010 data from ten French slaughterhouses. BMC Vet Res 2013; 9: 88.
14. Jaja I, Mushonga B, Green E, *et al*. Seasonal prevalence, body condition score and risk factors of bovine fasciolosis in South Africa. Vet Anim Sci 2017b; 4: 1-7
15. Phiri AM. Common conditions leading to cattle carcass and offal condemnations at three abattoirs in the Western Province of Zambia and their zoonotic implications to consumers. J S Afr Vet Assoc 2006; 77: 28-32.
16. Tembo W, Nonga HE. A survey of the causes of cattle organs and/or carcass condemnation, financial losses and magnitude of foetal wastage at an abattoir in Dodoma, Tanzania. Onderstepoort J Vet Res 2015; 82: 1-7.
17. Alemu A, Deneke Y, Ibrahim N. Major causes of organ condemnation and its financial loss in cattle in Gondar ELFORA abattoir. Ethiopia Res 2017; 9: 31-40.
18. Shaibu E, Atawalna J, Emikpe BO. Retrospective study on bovine whole carcass and liver condemnations with their associated direct financial losses at the Kumasi Abattoir, Ghana. Afr J Biomed Res 2017; 20: 45-52.
19. Ahmed S, Fentahun S, Bihonegn T, *et al*. Study on major causes of organs condemnation and financial loss in cattle slaughtered at Hayik Municipal Abattoir. J Anim Res 2019; 9: 201-207.
20. Komba EVG, Komba EV, Mkupasi EM, *et al*. Sanitary practices and occurrence of zoonotic conditions in cattle at slaughter in Morogoro Municipality, Tanzania: implications for public health. Tanzan J Health Res 2012; 14: 1-12.
21. Nzeyimana P, Habarugira G, Udahemuka JC, *et al*. Prevalence of bovine cysticercosis and age relationship at post-mortem in Nyagatare slaughterhouse. World Sci Res J 2015; 3: 29-33.
22. Hoffman LC, Lühl J. Causes of cattle bruising during handling and transport in Namibia. Meat Sci 2012; 92: 115-124.
23. Addis AB. Causes of organ condemnation and economic loss of cattle in developing countries. Review. Int J Eng Dev Res 2017; 5: 776-796.
24. Elemo KK, Hiko A, Dawud A. Bovine cysticercosis and human teniasis with public health implication at Asella Town, Arsi Zone of Oromia regional state, Ethiopia. Bull Anim Health Prod Afr 2017; 65: 49-59.
25. Lyimo EG, Ntikabuze BB, Olkitok MM, *et al*. Causes of organ condemnations and financial losses in cattle slaughtered at Mahenge slaughter facility in Ulanga District, Morogoro, Tanzania. Tanz Vet J 2018; 35: 138-144.
26. Ejeh EF, Paul BT, Lawan FA, *et al*. Seasonal prevalence of bovine fasciolosis and its direct economic losses due to liver condemnation at Makurdi abattoirs north central Nigeria. Sokoto J Vet Sci 2015; 13: 42-48.
27. Mochankana ME, Robertson ID. A retrospective study of the prevalence of bovine fasciolosis at major abattoirs in Botswana. Onderstepoort J Vet Res 2016; 83: 1-5.
28. Kouam MK, Meningue R, Fon DE. Parasitic causes of organ condemnation in cattle slaughtered in Fako abattoirs, South-West region of Cameroon, and estimate of financial losses. J Helminthol 2019; 93: 367-371.
29. Ahmad AM, Elsharawy NT. Condemned meat and offal from different slaughtered animals at two different environments. J Food Microbiol Saf Hyg 2018; 3: 2476-2059.
30. Tadesse M, Tesfaye S, Admasu P. Prevalence of Bovine hydatidosis and its economic importance in cattle slaughtered at Bahir Dar Municipal Abattoir, Northern Ethiopia. Int J Livest Res 2018; 6: 1-10.
31. Chinonyerem U, Kalu E. Prevalence of diseases/conditions that lead to condemnation of bovine organs/carcass at post-mortem examination. Glob Vet 2019; 21: 225-231.
32. Pfukenyi DM, Mukaratirwa S. A retrospective study of the prevalence and seasonal variation of *Fasciola gigantica* in cattle slaughtered in the major abattoirs

of Zimbabwe between 1990 and 1999. Onderstepoort J Vet Res 2004; 71: 181-187.
33. Mellau BL, Nonga HE, Karimuribo ED. Slaughter stock abattoir survey of carcasses and organ/offal condemnations in Arusha region, northern Tanzania. Trop Anim Health Prod 2011; 43: 857-864. DOI:10.1007/s11250-010-9773-1
34. Joan N, Stephen M, Bashir M, *et al*. Prevalence and economic impact of bovine fasciolosis at Kampala City Abattoir, Central Uganda. Microbiol Res J Int 2015; 7: 109-117.
35. Yimer A, Ayen M, Ali M, *et al*. Prevalence, cyst characterization and economic importance of bovine hydatidosis in Addis Ababa Abattoirs Enterprise, Ethiopia. J Anim Res 2016; 6: 375-379.
36. Eshetu E, Thomas N, Awukew A, *et al*. Study on the prevalence of bovine fasciolosis and estimated financial losses due to liver condemnation: In case of Angacha Woreda, Kambata Tembaro Zone, Southern Ethiopia. J Biol Agric Healthcare 2017; 7: 78-83.
37. Jaja IF, Mushonga B, Green E, *et al*. Factors responsible for the post-slaughter loss of carcass and offal's in abattoirs in South Africa. Acta Trop 2018; 178: 303-310.
38. Nyirenda SS, Sakala M, Moonde L, *et al*. Prevalence of bovine fascioliasis and economic impact associated with liver condemnation in abattoirs in Mongu district of Zambia. BMC Vet Res 2019; 15: 33.
39. Hajimohammadi B, Oryan A, Zohourtabar A, *et al*. Rate of carcass and offal condemnation in animals slaughtered at Yazd Slaughterhouse, central Iran. Asian Pac J Trop Biomed 2014; 4: 736-739.
40. Sheferaw D, Abdu K. Major causes of organ and carcass condemnation and associated financial losses in cattle slaughtered at Kombolcha ELFORA abattoir from 2008-2012, Ethiopia. Ethiopian Vet J 2017; 21: 54-66.
41. Opara M. Pathological conditions of condemned bovine lungs from abattoirs in Akwa Ibom State, Nigeria. Anim Res Int 2005; 2: 314-318. DOI: 10.4314/ari.v2i2.40859
42. Habarugira G, Rukelibuga J, Nanyingi MO, *et al*. Bovine tuberculosis in Rwanda: Prevalence and economic impact evaluation by meat inspection at Société des Abattoirs de Nyabugogo-Nyabugogo Abattoir, Kigali. J S Afr Vet Assoc 2014; 85: 1-5.
43. Opoku SO, Atawalna J, Daniel SD, *et al*. Abscessations and their associated microorganisms in slaughtered cattle at the Kumasi Metropolitan Abattoir, Ghana. East African Scholars J Agric Life Sci 2019; 2: 130-133.
44. Habarugira G, Mbasinga G, Mushonga B, *et al*. Pathological findings of condemned bovine liver specimens and associated economic loss at Nyabugogo abattoir, Kigali, Rwanda. Acta Trop 2016; 164: 27-32.
45. Aman H, Kassim S, Boru G, *et al*. Major causes of liver condemnation and associated direct financial losses in bovine slaughtered at Assela Municipal Abattoir Arsi, South Eastern Ethiopia. Glob J Med Res 2017; 16.
46. Alhaji NB, Yatswako S, Isola TO. A survey of organs/offal condemnations and foetal losses in slaughtered trade cattle at abattoirs in north-central Nigeria: major causes and associated economic implications. Bull Anim Health Prod Afr 2017; 65: 81–93.
47. Zeryehun T, Alemu B. Major gross lesions of lung in cattle slaughtered at Hawassa Municipal Abattoir, Southern Ethiopia. J Vet Med 2017. https://doi.org/10.1155/2017/1702852.
48. Mohammed A, Abdulai A, Birteeb PT, *et al*. Major causes of organ and carcass condemnations of cattle and their associated financial loss at the Tamale Abattoir, Ghana. UDS Int J Dev 2018; 5: 53-67.
49. Cruz-Monterrosa RG, Reséndiz-Cruz V, Rayas-Amor AA, et al. Bruises in beef cattle at slaughter in Mexico: implications on quality, safety and shelf life of the meat. Trop Anim Health Prod 2017; 49: 145-152.
50. Atawalna J, Gbordzi M, Emikpe BO, *et al*. Whole carcass and organ condemnation and their associated financial losses in ruminants slaughtered at the Bolgatanga municipal abattoir of Ghana. Int J Vet Sci 2016; 5: 5-9.
51. Swai ES, Ulicky E. An evaluation of the economic losses resulting from condemnation of cattle livers and loss of carcass weight due to fasciolosis: a case study from Hai town abattoir, Kilimanjaro region, Tanzania. Livest Res Rural Dev 2009; 21: 186.
52. Desie S, Kedir A. Major causes of organ and carcass condemnation and associated financial losses in cattle slaughtered at Kombolcha ELFORA abattoir from 2008-2012, Ethiopia. Ethiopian Vet J 2017; 21: 54-66.
53. Tlhapi PT. A critical evaluation of the causes of carcass condemnations in a South African cattle abattoir, Doctoral dissertation, University of Pretoria 2013.
54. Katjiteo ZK. Major causes of bovine carcasses and organs condemnation: a retrospective study on slaughtered animals at the Windhoek, Meatco Abattoir, Doctoral dissertation, University of Namibia 2001.
55. Shikongo-Kuvare LT. Development of risk communication strategies to improve control of *Cysticercosis bovis* in North Central Namibia, MSc dissertation, University of Pretoria 2007.
56. Dyab AK, Ahmed HA, Hefnawy YA, *et al*. Prevalence of tissue parasites in cattle and buffaloes

slaughtered in El-Minia Governorate Abattoirs, Egypt. PSM Vet Res 2019; 4: 49-58.
57. Dupuy C, Demont P, Ducrot C, *et al*. Factors associated with offal, partial and whole carcass condemnation in ten French cattle slaughterhouses, Meat Sci 2014; 97: 262-269.
58. Frandson, R.D., Wilke, W.L., Fails, A.D. 2009. Anatomy and physiology of farm animals. 7th ed. John Wiley & Sons. p 358-359.
59. Devlin, T.M., 2010. Textbook of Biochemistry with Clinical Correlations, 7th ed. Wiley.
60. Cullen JM, Brown DL. Hepatobiliary system and exocrine pancreas. Pathologic Basis of Veterinary Disease 5th ed. McGavin MD, Zachary JF, editors. Elsevier Mosby, St Louis; 2012. p 405-457.
61. Gu X, Manautou JE. Molecular mechanisms underlying chemical liver injury. Expert Rev Mol Med 2012; 14.
62. Macdonald AG, Bourgon SL, Palme R, *et al*. Evaluation of blood metabolites reflects presence or absence of liver abscesses in beef cattle. Vet Rec 2017; 4: e000170.
63. Abass KS, Mohammed NS, Taleb M, *et al*. Study of bovine and ovine pulmonary and hepatic abscessation at Kirkuk abattoir, Plant Arch 2019; 19: 1640-1644.
64. Tadepalli S, Narayanan SK, Stewart GC, *et al*. *Fusobacterium necrophorum*: A ruminal bacterium that invades liver to cause abscesses in cattle. Anaerobe 2009; 15: 36–43.
65. Keele JW, Kuehn LA, McDaneld TG, *et al*. Genome wide association study of liver abscess in beef cattle. J Anim Sci 2016; 94: 490-499.
66. Reinhardt CD, Hubbert ME. Control of liver abscesses in feedlot cattle: a review. Prof Anim Sci 2015; 31: 101-108.
67. Amachawadi RG, Nagaraja TG. Liver abscesses in cattle: A review of incidence in Holsteins and of bacteriology and vaccine approaches to control in feedlot cattle. J Anim Sci 2016; 94: 1620-1632.
68. Radostits, O.M., Gay, C.C., Hinchcliff, K.W., *et al*. 2006. A textbook of the diseases of cattle, horses, sheep, pigs and goats. Elsevier Health Sciences.
69. Lopez A. Respiratory system, mediastinum and pleurae. Pathologic Basis of Veterinary Disease, 5th ed. Zachary JF, McGavin MD, editors. St. Louis, Mosby Elsevier, USA: 2012. p. 458–538.
70. Erickson, H.H., Goff, J.P., Uemura, E.E. 2015. Dukes' physiology of domestic animals. John Wiley & Sons.
71. WHO. Echinococcosis. Available at: https://www.who.int/health-topics/echinococcosis/#tab=tab_1. Cited April 1, 2020.
72. Harris MK, Eastwood LC, Boykin CA, *et al*. National Beef Quality Audit–2016: assessment of cattle hide characteristics, offal condemnations, and carcass traits to determine the quality status of the market cow and bull beef industry. Transl Anim Sci 2018; 2: 37-49.
73. Kandiwa E, Madzingira O, Mushonga B, *et al*. A 13-year retrospective study of the beef and dairy cattle losses at Neudamm Farm in the Khomas region of Namibia, Alex J Vet Sci 2017; 55: 8-20.
74. Kandiwa E, Mushonga B, Samkange A, *et al*. Retrospective study on small ruminant losses in a farm of Namibia. Indian J Small Ruminants 2018; 24: 115-120.
75. Mohamadin SA, Abdelgadir AE. Study on hydatid cyst infection in slaughterhouses in Khartoum state, Sudan. Arch Appl Sci Res 2011; 3: 18-23.
76. Khan AM, Gazi M, Bashir S. Seasonal prevalence of hydatidosis in buffaloes–A retrospective study. Vet World 2013; 6: 647-650.